



Biostratigraphic and Paleoenvironmental Study of Outcrop Samples Exposed Along Calabar/ Odukpani Junction in Calabar Flank, Southeastern Nigeria

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Received: 27 May 2017, Revised Received: 11 July 2017, Accepted: 12 July 2017

Abstract

Foraminiferal investigation of outcrop samples exposed along the newly constructed truck carriage way of United Cement Company (Unicem), along Calabar/ Odukpani Junction, Southeastern Nigeria was carried out. The aim of this work was to infer the age, paleobathymetry and paleoecology and paleodepositional environmental interpretation of the investigated samples. The lithology consists predominantly of dark grey to light brown shale with minor smoky white, fine to medium siltstone and sand intercalations. The foraminiferal assemblages constitute 98% of the recovered taxa and are made up of 84% planktonic and 16% arenaceous benthics taxa. Few accessories including gastropoda, ostracoda, fish teeth and conodont were present and constitute less than 2% of the overall assemblage encountered. Base on the occurrence of the following foraminiferal taxa; *Guembelitria cenomana*, *Heterohelix reussi*, *Hedbergella detrioensis*, *Hedbergella planispira* and *Ammobaculites amabensis*, the sediments were probably deposited during Cenomanian-Turonian times. However, the occurrences of the above mentioned taxa put these sediments to belong to the Ekenkpon Shale. The paleobathymetric delineation in this study ranges from Shallow Inner Neritic - Outer Neritic paleo-water depths. The paleoecological analysis showed that the sediment were deposited in restricted low oxygen circulation bottom condition in some instances and the salinity ranges from low to normal saline water condition which is probably due to the presence of minor agglutinating and hyaline species. The general depositional environment is Coastal plain/ estuarine - Open marine settings.

Keywords: Foraminifera, Paleobathymetry, Paleoecology, Paleoenvironment, Cenomanian-Turonian, Ekenkpon Shale and Calabar Flank.

Introduction

Biostratigraphy has become an increasing tool in studying some of the non-oil or oil potential basins in

Nigeria. Foraminiferal biostratigraphy is one of such tools that can be applied in this method. Presently, Calabar Flank which is a non-oil producing sedimentary basin in Nigeria has received very low

input from researchers. The push for this work was to determine the age and paleoenvironmental interpretation of outcrop section exposed along Calabar/ Odukpani Junction, Southeastern Nigeria. The geographical coordinates of the investigated area is between latitude and longitude $N05^{\circ} 08' 56.2''$ and $E08^{\circ} 20' 18.2''$ respectively (Fig.1).

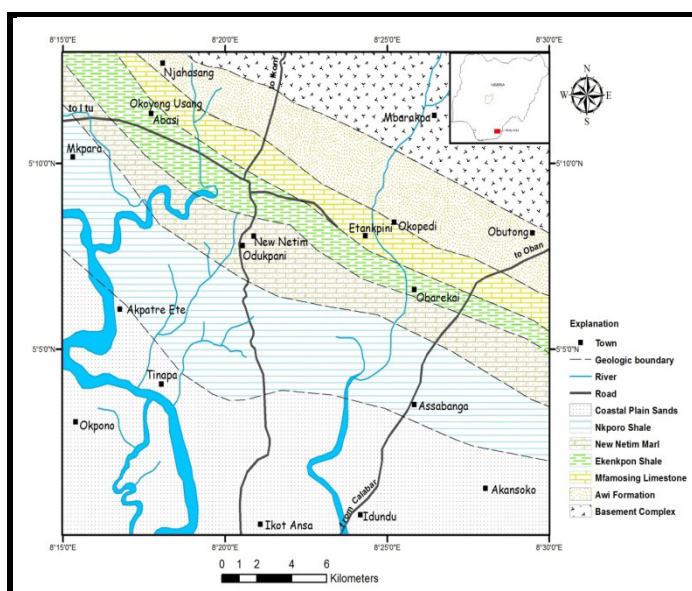


Figure 1. Geologic map of the study area.

Objective of study

The main objective of this research work is to determine age and carried out paleoenvironmental interpretation of these outcrop samples exposed along Calabar/ Odukpani Junction, Southeastern Nigeria. A secondary objective will be to find the actual position of this outcrop samples in the stratigraphic column of Calabar flank. The limitation encountered in this study was of insufficient equipment to carry out palynological analysis of the sample which would have correlated the two results for a better interpretation. Also a high resolution microscope was not available for systematic studies of identified taxa. The encountered effect which has been experienced as a result of the above mentioned limitation includes inability to clearly identified detailed taxonomic

features. This however, may hinder the possibility of carrying correct identification of the encountered taxa with respect to their genus and species groups respectively.

Geological setting

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria (Murat, 1972). The basin according to Nyong (1995) is bounded by the Oban Massif in the north, Calabar hinge line separates the basin from Niger Delta basin in the south, Ikpe platform and Cameroon volcanic trend delineate it in the west and east respectively (Fig. 2). The origin of this basin is associated with the opening of the South Atlantic in the Mesozoic era when the South American plate drifted away from African plate. The major tectonic structures operating within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that influenced the distribution sedimentary facies (Murat, 1972 and Nyong, 1995).

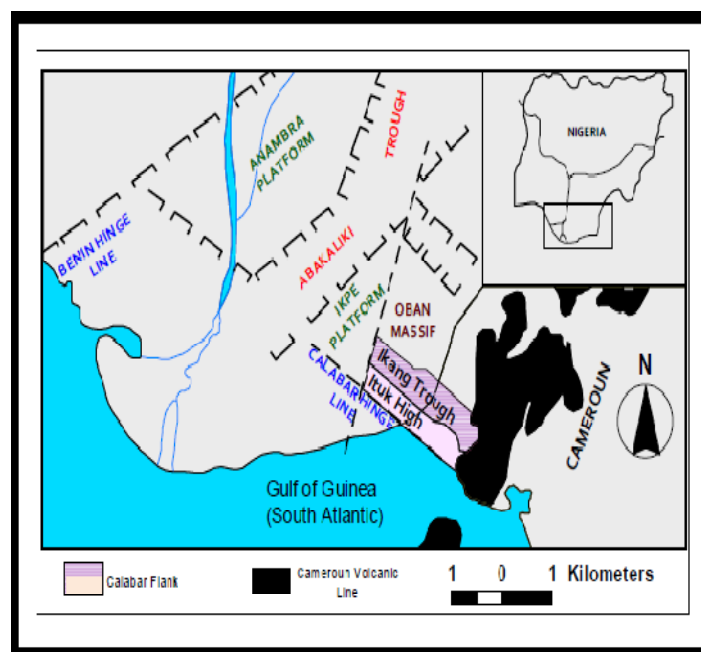


Figure 2. Map showing Calabar Flank location with respect to the Benue Trough (Nyong and Ramanathan, 1985).

Table1. Lithostratigraphic correlation between Calabar Flank, Abakaliki Trough, Anambra Basin and the middle Benue Trough (After Nyong, 1995 and Petters et al., 2010)

AGE	GSN 1957	Reyment 1965	Murat 1972 Anambra - Calabar	Dessauvage 1974 Anambra-Calabar	Petters et al., 1995 Calabar Flank	Petters et. al., 2010 Calabar Flank	
Quaternary	Coastal Plain Sands		Coastal Plain Sands	Benin Formation	Benin Formation	Benin Formation	
Pliocene				Ogwashi - Asaba Formation			
Miocene				Ameki Formation			
Oligocene				Imo Shale			
Eocene	Lignite Formation Bende Ameki Group	Nkporo Shales	Ameki Formation	Nsukka Ajali Mamu Enugu Shale	Nkporo Shale	Nkporo Shale	
Paleocene	Imo clay Shale Group		Imo Shale				
Maastrichtian	Thin bedded sandstones Lower coal measures		Nsukka Formation				
Campanian	Asata - Nkporo Shale group		Nkporo Shale				
Santonian	Agwu - Ndeaboh Shale Group	Eze - Aku Formation	Agwu Shale	Agwu Shale	New Netim Marl		
Coniacian			Eze - Aku Shale Group	Eze - Aku			
Turonian	Eze - Aku Shale Group		Asu River Group	Asu River Group			
Cenomanian	Odokpani Formation		Basal Grits	Basal Grits			
Albian	Asu River Group	Odokpani Formation			Mfamosing Limestone	Mfamosing Limestone	
Aptian							
Precambrian	BASEMENT	COMPLEX	BASEMENT	COMPLEX	BASEMENT	COMPLEX	

The stratigraphic succession in the Calabar Flank is shown in table 1. Sediment thickness is over 3500m with the onlap (or featheredge) of the outcropping units, along the fringes of the Oban Massif basement complex. The Formations are best exposed along Calabar –Ikom road and a succession consists of five (5) Cretaceous and a Tertiary lithostratigraphic units. Awi Formation is the oldest basal unit and sits non-conformably on the basement complex of Oban Massif. The Formation is Aptian in Age (Adeleye and Fayose, 1978). This is overlain by Mfamosing Limestone of Middle- Upper- Albian age (Petters, 1982) which

indicates the first marine transgression into the basin. This in turn is succeeded by Late Albian- Cenomanian through Turonian age, Ekenkpon Shale subsidence on the faulted blocks of horst and graben allowed wide spread deposition of shales with minor marl and mudstone intercalation. The New Netim Marl of Coniacian (Nyong, 1995) in age, succeeded the shale. The Santonian period was marked by a major unconformity in Nigeria. Nkporo Shale of Late Campanian to Early Maastrichtian (Edet and Nyong, 1994) capped marine transgression and Mesozoic sedimentation in Calabar Flank.



Figure 3. The outcrop of the studied section.

Materials and Methods

An approximately 11.0m thick shale outcrop sampled was investigated from the base to the top (Fig.3) within the study area. Samples were picked at different predetermined spot. The retrieved samples were collected into different secured and well-labeled sample bags. This was done in order to avoid contaminating the picked samples.

Sample list showing the respective location of the picked samples were prepared as this will help the laboratory technologist while preparing those samples should there be any missing depth. A standard weight of 20g for each sample was soaked with one teaspoonful of anhydrous Sodium carbonate with water for thorough disintegration overnight. After disaggregation, the samples were then washed through a running water-tap over a 63µm mesh-sieve. The washed residues were then dried over a hotplate at a minimum temperature of 20°C and then sieved into three main size fractions, namely; coarse, medium and fine grains. They were then stored into well label sample bags.

All the sized fractions were examined in a picking tray with a stable hair paint brush (N0000) under a binocular microscope. The gridlines on the picking tray ensured that every compartment of tray where the

sample was sprayed is picked. Picking was done with the aid of a fine portion of a water-moistened brush and dislodge it by stroking the brush gently on the mounted surface of the slide and covered with a micropaleontological cover slips. They were then arranged serially according to the increasing depth of the exposed outcrop sample, in a slide tray for easy identification. The foraminifers were then mounted on microfossil slides and sorted into morphological similar species. The identification of various foraminiferal taxa was done basically by comparing the recovered taxa with forms that have been previously published by various authors (Loeblich and Tappan, 1964; Bolli and Saunders, 1985 and Petters, 1982).

The resultant dried residues left were properly bagged for proper lithological description. These residues were used for lithologic analysis by examining each interval under binocular microscope. The lithologic description involves grain size, sorting, grain constituents and mineral accessories. However, 10% of diluted Hydrochloric acid was used on the samples to infer the presence or absence of calcareous minerals and species remains.

Results and Discussion

Lithologic Analysis

The lithostratigraphic study of the area consists predominantly of shale with rare occurrences of sand and siltstone (Table 2; Figs. 3 and 4). The shale sediments account for about 85% of the total outcrop sample recovered from the study location. The shale deposits are made up of light to dark grey and sometimes light brown, subfissile to fissile, moderately hard, carbonaceous and micromicaceous. The intercalated siltstones described from these sediments were found to constitute about 10% with the exception of sediments collected from L5E and L5G respectively. Their lithologic characteristics include

Table 2. Lithological description from the study area.

S/No	Depth/Location	Sediment	Description
1	L5 A (1m)	Shale 100%	Dark grey to sometimes light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and ferruginized. Traces of fine grained sand occur.
2	L5B (1.4m)	Shale 95%	Dark grey to light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and highly ferruginized.
		Sand 5%	Smoky white, fine to medium grained, well sorted, subangular to subrounded and slightly ferruginized.
3	L5C (2.9m)	Shale 95%	A/a
		Sand 5%	A/a
4	L5D (3.57m)	Shale 90%	A/a
		Sand 10%	A/a but sometimes coarse grained and ferruginized.
5	L5E (5.97m)	Siltstone 80%	Earthy brown to reddish, moderately hard and consolidated, calcareous and carbonaceous.
		Sand 20%	Smoky white, fine grained, but sometimes medium grained, well sorted, subrounded to subangular and slightly ferruginized. Traces of shale also occur.
6	L5F (6.87m)	Shale 100%	Dark grey to light brown, moderately hard to hard, fissile to subfissile, calcareous, carbonaceous and micromicaceous. Traces of subrounded fine to medium grained sand occur.
7	L5G	Siltstone 60%	Brown to reddish brown, hard to moderately hard, consolidated and massive, calcareous and micromicaceous.
		Shale 30%	Dark grey to light brown, moderately hard, fissile to subfissile, calcareous, micromicaceous., carbonaceous and highly ferruginized.
		Sand 10%	Smoky white, fine grained, well sorted, subangular to subrounded and highly ferruginized.
8	L5H (8.47m)	Shale 95%	A/a
		Sand 5%	A/a
9	L5I (9.1m)	Shale 100%	A/a but with abundant gypsum. Also traces of coarse grained sand are found.
10	L5J (10.7m)	Shale 100%	Dark to light grey, moderately hard, subfissile to fissile, calcareous, carbonaceous and micromicaceous. Traces of sand occur.

Note: A/a = As above

earthy brown to reddish, moderately hard and consolidated, calcareous and carbonaceous while the sand deposits were observed to constitute about 5% and are made up of smoky to off white, very fine -fine grained but sometimes medium grained, well sorted, subrounded to subangular and slightly ferruginized.

Biostratigraphic Analysis and Interpretation

The foraminiferal analysis of the study section yielded low to moderate abundance and diverse taxa, except at location L15 which yielded only one species of *Heterohelix reussi*. The identification of the recovered foraminiferal taxa was done in comparison with the work of Bolli and Saunders (1985) and other

published materials. From the analyzed samples, a total of 952 (about 92%) foraminiferal taxa and 18 (2%) macrofossils including ostracoda and gastropoda were recovered. The occurrence of the foraminiferal abundance in the investigated area is made up of 81.0% of calcareous and planktic taxa consisting of *Hedbergella delrioensis*, *Hedbergella planispira*, *Hedbergella* sp, *Heterohelix reussi*, *Heterohelix* sp, *Guembelitra cenomana*, with *Ammobaculites amabensis*, *Ammobaculites* sp. and *Haplophragmoides* sp. However, 16.2% of the recorded taxa represent the agglutinated benthic foraminifera (Fig. 4). Some of the recovered and identified taxa in the investigated area are shown in Plate 1.

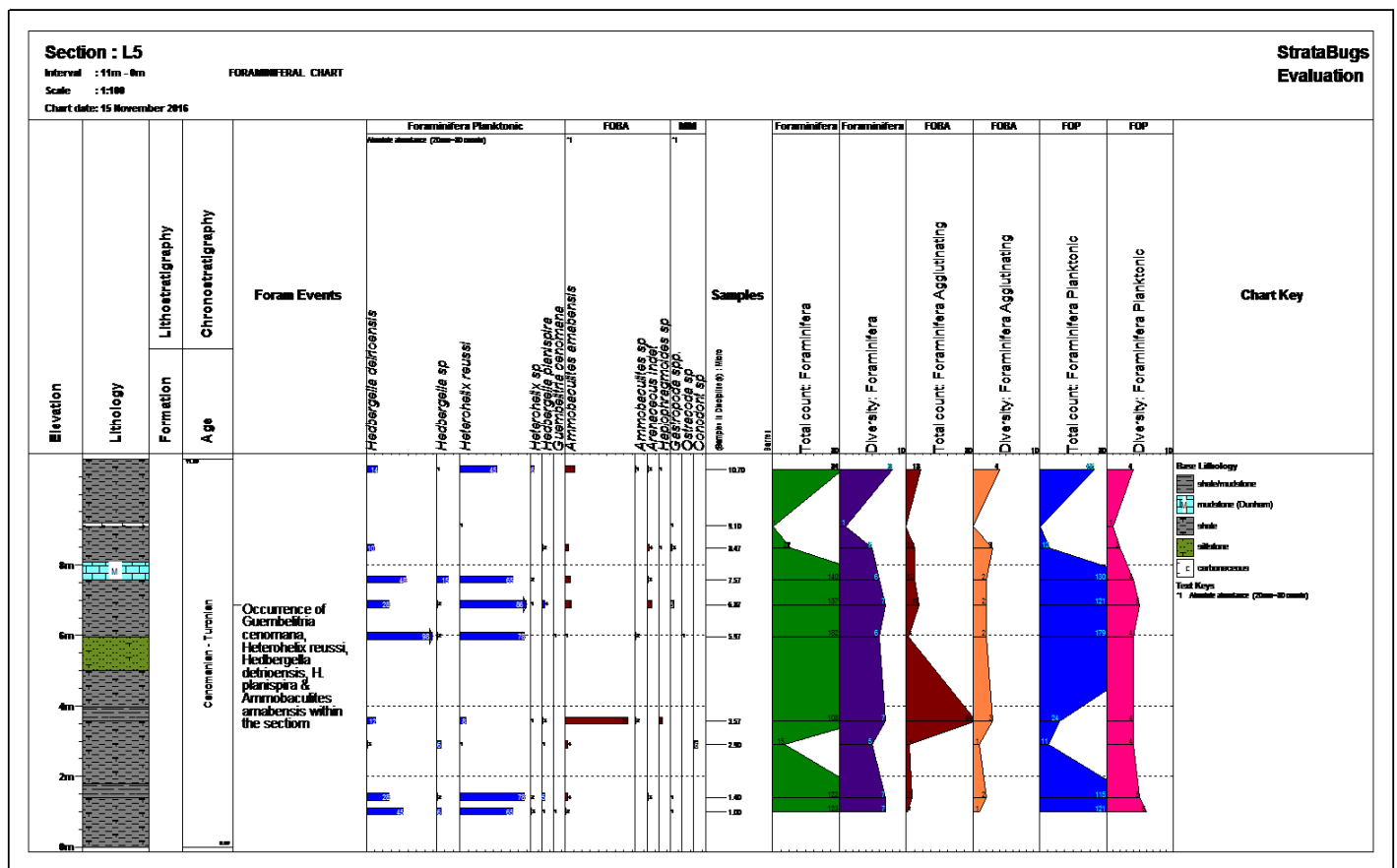
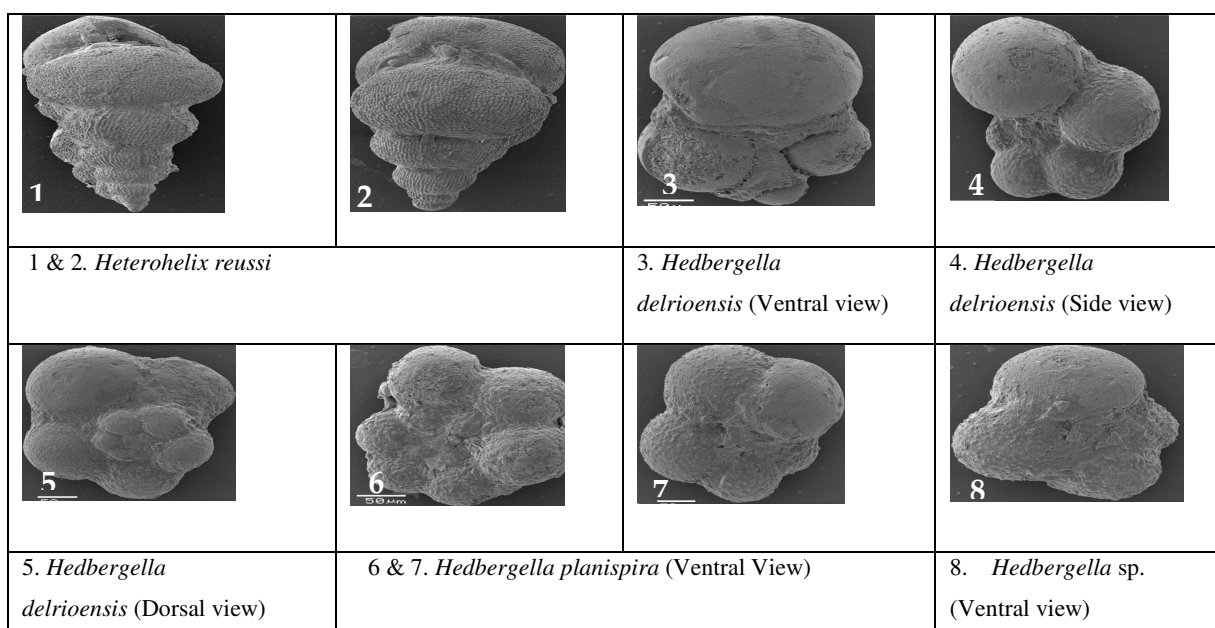


Figure 4. Foraminiferal distribution chart of the studied outcrop section.

Plate 1. Some of the identified foraminiferal taxa from the study section.



The foraminiferal biozonation of the study area is based on the approach of Bolli and Saunders (1985) and Petters, (1982). Based on this technique, the age of the investigated sedimentary section ranges from Cenomanian to Turonian. The occurrence of *Hedbergella* genera is mostly restricted to Cenomanian age. The occurrence of the planktic species such as *Hedbergella delrioensis*, *Hedbergella planispira*, and *Hedbergella* sp. infer sediments not older than the Cenomanian age (Petters 1982) to the studied samples. The occurrence of *Guembelitra cenomana* taxa observed within the base and the continuous occurrence of *Heterohelix reussi* taxa towards the top of this section however, showed that this section falls within the designated age of Cenomanian – Turonian (Bolli and Saunders, 1985).

Paleoenvironmental and Ecological Analysis

The lithologic description/analysis of the samples in the studied area show that about 85% of the sample is predominantly shale while the remaining portion accounts for siltstone and sandstone constituents as this may slightly infer minor influence of marine setting within the environment.

The planktic/benthic foraminiferal ratio is one of the methods used in inferring the water depth at the time those sediments was deposited. According to Haq and Boersma (1988) increase in ratio and abundance of calcareous species in sediment depicts increase in seaward deposition and sedimentation. Conversely, decrease in the ratio and abundance of arenaceous taxa decreases with water depth. This therefore implies that higher planktonic ratio within this study area denotes an open marine while lower ratio signifies shallow /brackish water or low water depth. The ratio of planktonic to benthonic foraminifera (P/B ratio) from the investigated area ranges from 80%/20% to 98.4% /1.6% respectively. These values indicate paleo water-depths of inner to Outer Neritic (shelf) environment of deposition (Culver, 1988).

In a low salinity environment, agglutinated species predominates over the calcareous counterparts because their test do not require high amount of Calcium carbonate to construct their shell. This therefore implies that the agglutinants live more successful in very low saline water. The arenaceous benthic foraminiferal taxa recovered from this study are only very small fraction of approximately 16% and this represents low saline water. Conversely, rotalina/hyaline types of foraminifera are restricted to normal and/or high salinity conditions due to the fact, they require large amount of calcium carbonate to precipitate their shells (Greiner, 1969 and Peryt, 2004). As the test type is the function of environment, most of the samples studied in the investigated area can be summarized as originating from normal marine to low marine saline water. This also implies that the predominantly calcareous hyaline test over agglutinating taxa may have originated from open marine to coastal plain setting. The present of some non foraminiferal fossils referred as accessories including fragments of gastropods and ostracods, averaging the population density of approximately two percent are also inferred as marine setting.

The Late Cenomanian low oxygen tolerant benthic foraminiferal faunas recorded here have been equally recorded and reported from many regions of the world and was believed to represent the most stressful environmental conditions. This may have resulted in the increasing rate of oxygen depletion which caused stepped extinction or temporary disappearance of several benthic species. It is believed that agglutinated benthic foraminifera such as *Ammobaculites* and *Haplophragmoides* species can thrive in an environment with low dissolved oxygen. Their occurrence within the studied interval depicts a low bottom oxygen circulation in a stressful condition.

Conclusion

The biostratigraphy and paleoenvironmental studies of outcrop samples exposed along Calabar/Odukpani Junction, Southeastern Nigeria was carried out utilizing foraminiferal analysis. Based on the aforementioned analysis, associated index taxa such as *Heterohelix reussi*, *Ammobaculites amabensis* and *Guembelitra cenomana* was recovered and identified within the studied samples. This puts the epoch of the studied section as Cenomanian to Turonian times. The paleobathymetry and paleoecological analysis show that the sediments were deposited in the neritic zone of restricted oxygen circulation occurring within low to normal water saline. The depositional environment of the investigated section is of Coastal plain to Open marine settings. The lithologic mainly content consists of dark grey, fissile to subfissile shale, with minor occurrence of earthy brown to reddish siltstone and sandstone sediments. This study further shows that sediments belonging to the Calabar/ Odukpani Junction Southeastern Nigeria is part of Ekenkpon Formation in Calabar Flank, which is equivalent to EzeAku in the Lower Benue Trough.

Acknowledgement

Useful criticisms and suggestions received from Prof. Etie Ben Akpan and Associate Professor Edet Amah (lecturers, Department of Geology, University of Calabar, Nigeria) are greatly acknowledged. The Department of Geology, University of Calabar is also commended for the good learning atmosphere given to the first author.

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Cite this article: Una, E.E., Itam, A.E., Udoh, M.U. and Inyang, D.O. 2017. Biostratigraphic and Paleoenvironmental Study of Outcrop Samples Exposed Along Calabar/Odukpani Junction in Calabar Flank, Southeastern Nigeria. *International Basic and Applied Research Journal*, Volume 03, Number 10, pp. 1-9.